Acta Botanica Hungarica 46 (3–4), pp. 337–361, 2004

FOLIAR ANATOMY ON TWELVE GENERA OF BIGNONIACEAE (LAMIALES)

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(Received 31 May, 2003)

The foliar anatomy of the 12 genera (16 species) of Bignoniaceae found in West Africa was studied and compared. Observations were carried out by light microscope (LM) and scanning electron microscope (SEM). Across the family, anatomical characters found to be most useful are: stomata type, trichomes in the adult material, presence of peristomatal folds, type of sinuosity of epidermal anticlinal wall, veinlet termination number, cuticular striation, presence of sclerenchymatous idioblasts in the mesophyll, presence of hypodermis, presence of sclerenchymatous fibres in the ground parenchyma and presence of collenchyma in the outer tissue of petiole. These characters have been used in a key to the species.

Key words: capitate gland, peristomatal, ridged, sclerenchymatous idioblast

INTRODUCTION

Bignoniaceae is a moderate size group of shrubs, lianas, climbers and trees that are distributed in pantropical regions, especially in the New World tropics, with a few temperate taxa. The family consists of 110 genera and 650 species (WISC 1999). The major economic contributions of the Bignoniaceae are to medicine and ornamental and wood uses in various countries. The medicinal value of some members of the Bignoniaceae in West Africa is well documented by authors such as Oliver (1960), Irvine (1961), Ayensu (1978) and Burkill (1987), among others.

A review of the literature shows that few microscopic observations have been published on the anatomy of the Bignoniaceae in West Africa apart from the work of Metcalfe and Chalk (1979), Hyakutake (1965), Jain (1978*a*, *b*), Jain and Singh (1980), Menhra and Kulkarni (1989) and Piazzano-Marianela (1999).

Several workers have established that leaf anatomical characters are of considerable diagnostic value and may also be of assistance in elucidating taxonomic relationships (Stace 1965, for review). This study reports the pattern of variation in epidermal characteristics of 16 taxa and assesses their value in spe-

0236–6495/$ 20.00

cies identification and classification, and contributes to the project on comparative systematic anatomy within the Bignoniaceae.

MATERIALS AND METHODS

A list of materials used in the present study is given in the Appendix. Dried material was obtained from the voucher specimens deposited in FHI, IFE and LUH. Fresh specimens were collected in the wild; resulting voucher specimens were deposited in LUH. Herbarium abbreviations follow Holmgren *et al*. (1981). Small samples (1–2 cm^2) of mature leaves were taken from the standard median level (midway between the base and apex of lamina) of each leaf.

Dried materials were rehydrated by soaking in a solution of 25% potassium hydroxide until they sank and regained the shape and texture of fresh material. Cuticular preparation was made by using the techniques of Ogundipe (1992) with some modification. Squares of 5–8 mm were taken from identical regions of each leaf, usually midway between the base and apex of the lamina. Each sample was immersed in concentrated nitric acid for 2–3 days, depending on the nature of the leaf. Adaxial and abaxial epidermises were then separated using forceps and a camel hair brush. The samples were rinsed in several changes of water to remove the nitric acid, and stained in a 3% aqueous solution of Safranin O. Then they were washed in 2 to 3 changes of 50% ethanol to remove excess stain, and mounted in glycerine.

Leaf transverse sections, 10–15 µm thick, were cut halfway along the lamina using a sliding microtome. The sections were cleared in a 50% bleaching reagent and washed in 3 or 4 changes of water before staining in 3% aqueous Safranin O and counter stained in 1% aqueous Alcian Blue. Excess stain was removed in 2 or 3 changes of 50% ethanol; the sections were then mounted in glycerine.

Leaf materials were examined by light microscopy (LM) and scanning electron microscopy (SEM). Small pieces (7 mm^2) of leaf material were fixed on SEM stubs with double-sided tape, coated with gold in a sputter coater, and examined in a JEOL JSM 840A SEM at the Electron Microscope Unit of the Biology Department, Central Michigan University.

Drawings were made using camera lucida or images were computerised digitally with a SPOT camera mounted on a Zeiss Axiophot Microscope.

All measurements in LM were made using a calibrated eyepiece micrometer with a ×40 objective. From each species 50 cells and stomata were randomly selected for measurement. Values for aperture outline area were calculated using the Dickie and Gasson (1999) method, calculating from paired aperture outline length and width measurements assuming an elliptical shape.

Statistical analysis (correlation) was carried out using the data analysis tool Microsoft 2000 Excel.

OBSERVATIONS

Morphological features of the epidermis, given below, are summarised in Tables 1 and 2 and Figures 1–70.

Leaf surface

Epidermal cells (Table 1, 1–12): epidermal cells are mostly polygonal on the adaxial surface, but vary from polygonal to irregular on the abaxial surface. The cells vary in size both within and between species with the abaxial cells smaller than the adaxial cells.

Adaxial and abaxial cells over the midrib (costal zone) elongated rectangular with long arms, which are straight to wavy (Figs 5, 36–38), and have regular arrangements in rows with straight to oblique end walls.

Cuticle: (i) abaxial, ridged in *Jacaranda mimosifolia* (Fig. 51), striated in *Parmentiera venusta* (Fig. 1), *Haplophragma adenophylla* (Fig. 3), *Markhamia lutea* (Fig. 45), *M. tomentosa* (Fig. 47) and *Kigelia africana* but smooth in other ten taxa.

(ii) adaxial: cuticle non-striate in all except *Stereospermum acuminatissimum* and *Parmentiera venusta* (Figs 2, 35) where striated, and ridged on *Crescentia cujete* (Fig. 27).

Epicuticular wax: granular in all taxa except in *J. mimosifolia* and *P. venusta* where it appeared as flakes. The wax dissolved when immersed in hot chloroform.

Stomata (Table 2, Figs 2–3, 7, 9, 11, 39–59). All species studied are hypostomatic. Four distinct stomatal types were recognised = paracytic, diacytic, anomocytic and anisocytic. Paracytic stomata where observed only in *Stereospermum kunthianum*; diacytic type only in *K. africana;* anisocytic type only in *Rhodocolea racemosa* (Fig. 7). Anomocytic type only is recorded in *Parmentiera cerufera* (Fig. 1), *H. adenophylla* (Fig. 3), *M. obtussiflora*, *M. lutea*, *Tecomaria capensis*, *J. mimosifolia* and *Stereospermum acuminatissimum.* Combinations of anomocytic and diacytic where observed in *M. tomentosa*, *Tabebuia palluda*, anomocytic and anisocytic in *Spathodea campanulata* and *Newbouldia leavis* (Fig. 9*).* In *C. cujete* (Fig. 42), *Tabebuia palluda* (Fig. 59), and *J. mimosifolia* (Fig. 52) peristomatal ridges are present. Rim width varies from 2.5 µm in *P. cerufera* to 6.5 µm in *M. palluda*. Aperture outline area varies from 7.8 µm^2 in *C. cujete* to 57.2 µm^2 in *M. palluda*.

Table 1

Epidermal features of West African Bignoniaceae. Abbreviations: C = Cuticular ornamentation, V = Veinlet termination No, P = Palisade ratio, pol. = polygonal, irreg. = irregular, str. = straight, arc. = arcuate, sin. = sinuous, sm. = smooth, stri. = striated, rid. = ridged, com. = common, abu. = abundant

Taxa	Cell shape	Anti-clinal wall pattern	No of cells/ view	Epidermis		C	V	P	Trichomes		Inclusion
				Length (µm)	Width (µm)				Den-sity	Type	
Markhamia obtussiflora	Ab. pol.	str./arc.	56	21.0(22.2)23.0	12.0(13.1)13.8	sm.			com.	a. f, b	st; oct
	Ad. pol.	str.	102	18.0(18.7)19.1	15.5(15.9)16.7	sm.	0	5–8	com.	a, f, b	st; oct
Markhamia lutea	Ab. pol.	str./arc.	79	15.0(16.0)16.8	10.0(11.2)11.9	stri.			abu.	b, f	st; pr
	Ad. pol.	str.	105	17.1(18.0)19.0	13.4(14.8)15.5	sm.	1–2	7–9	com.	b, f	st; pr
Markhamia tomentosa	Ab. pol.	str./arc.	65	17.1(18.1)19.0	12.5(13.0)13.9	stri.			abu.	b, f	st; oct
	Ad. pol.	str.	103	12.1(13.7)14.3	11.5(12.3)13.0	sm.	0	5–6	abu.	f	st; oct
Tabebuia palluda	Ab. pol.	str./arc.	77	23.0(24.9)25.3	10.0(11.2)12.2	sm.			com.	a, c, f, g, b	st; pr; oct
	Ad. pol.	str.	110	14.3(15.2)16.8	13.2(13.9)14.5	sm.	0–1	5–6	abu.	a, c, f, g, b	st; pr; oct
Tecomaria capensis	Ab. pol.	str./arc.	54	25.6(26.7)27.8	18.6(19.2)20.1	sm.			abu.	a, c, f, e	st; oct
	Ad. pol.	str./arc.	98	25.3(26.3)27.7	14.4(15.5)16.1	sm.	0–3	4–5	abu.	a, c, f,	st;pr;sp;oct
Newbouldia leavis	Ab. irreg.	arc./sin.	57	17.8(18.8)19.0	13.9(14.9)15.1	sm.			com.	a, f, g	st; pr; crs; oct
	Ad. pol.	str.	101	20.3(21.2)22.2	10.5(11.2)12.4	sm.	1–2	6–7	com.	a, f, g	st; pr;crs;oct
Jacaranda mimosifolia	Ab. irreg.	sin.	70	20.3(21.2)22.8	10.5(11.2)12.0	rid.			com.	a, e, f, g	st; pr; crs; oct
	Ad. pol.	str.	112	12.3(12.9)13.2	9.2(10.1)10.9	sm.	0	4–6	com.	a, e, f, g	st; pr; crs; oct
Stereospermum kunthianum	Ab. irreg.	sin.	75	15.1(16.0)17.2	10.4(11.2)12.3	sm.			abu.	b, f	st; pr; crs
	Ad. pol.	str./arc.	48	29.2(21.9)33.01	20.6(21.2)22.3	sm.	0–1	14–16	abu.	b, f	st; pr; crs
Stereospermum acuminatissimum	Ab. irreg.	sin	87	14.3(15.8817.02	9.9(10.9)12.3	stri.			abu.	a, b, f	st; pr; crs
	Ad. pol.	str.	43	28.7(30.3)31.2	21.2(22.8)23.1	stri.	0–1	9–10	abu.	a, b, f	st; pr; crs
Kigelia africana	Ab. irreg.	str.	60	16.4(17.9)18.9	13.6(15,2)16.1	stri.			abu.	a, b, f, e, g	st; pr; crs

Note: figures in bracket are mean values. Those not in bracket represent the extremes of values. Ab = abaxial, Ad = adaxial, a = acicular, b = filiform, c = dendric, d = fasciculate, e = subulate, f = peltate scale, g = capitate gland, oct = octahedra, pr = prismatic, crs = crystal sand, st = starch grains

Table 1 (continued)

Taxa	Cell shape	Anti-clinal wall pattern	No of cells / view	Epidermis		C	V	P	Trichomes		Inclusion
				Length (µm)	Width (µm)				Den-sity	Type	
Parmentiera cerufera	Ab. irreg.	sin.	53	16.8(17.3)18.9	13.3(14.4)16.2	sm.			abu.	b, f	st; pr; crs
	Ad. pol.	str./arc.	72	22.1(23.0)25.0	18.3(19.6)20.3	sm.	0–1	9–10	abu.	f	st; pr; crs
Parmentiera venusta	Ab. irreg.	sin.	70	26.4(27.9)28.3	10.1(11.9)12.4	stri.			abu.	a, f	st; pr; crs
	Ad. pol.	str.	50	23.4(24.4)25.7	20.2(22.1)23.4	stri.	4–5	6–7	abu.	a,	st; pr; crs
Haplophragma adenophylla	Ab. irreg.	sin.	67	20.3(21.3)22.4	17.5(18.3)19.3	stri.			abu.	d, f	st; pr; crs
	Ad. pol.	str./arc.	103	20.5(21.9)23.5	10.7(12.8)13.4	sm.	1–2	5–7	com.	d, f	st; pr
Rhodocolea racemosa	Ad. pol.	str./arc.	50	22.5(23.3)24.5	17.5(18.8)20.7	sm.			com.	f	st, crs
	Ad. pol.	str.	64	20.3(21.8)22.8	15.9(16.6)17.3	sm.	0–1	6–7	com.	f	
Crescentia cujete	Ad. pol.	str.	50	17.5(18.6)19.5	14.9(15.9)16.3	sm.			com.	a, f	st; crs
	Ad. pol.	str.	101	20.2(21.2)22.1	16.1(16.9)17.0	rid.	1–2	7–8	com.	a, f	st; crs
Spathodea campanulata	Ad. pol.	str./arc.	72	19.1(20.4)21.3	16.0(17.8)18.8	sm.			com.	a, b, f	st, pr,
	Ad. pol.	str.	98	17.3(18.9)19.6	15.3(16.4)18.0	sm.	2–4	8–10	com.	a, b, f	st, pr

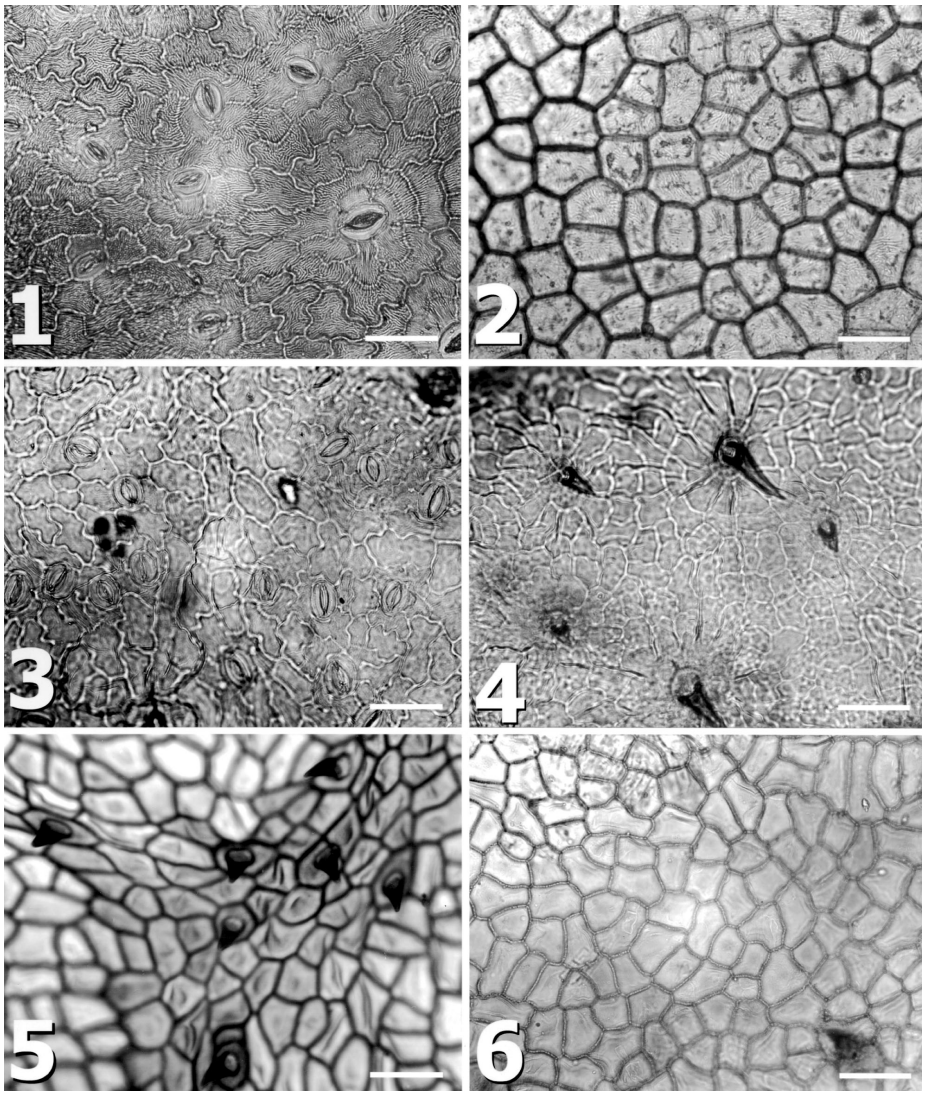
Table 2

Variations in stomatal characters of West African Bignoniaceae. Abbreviations: E = elevation, F = frequency, Ap. = Aperture outline, Ab = abaxial, A = raised above the other epidermis, B = at the same level as other epidermal cells, C = sunken (guard cells and stomatal pore), ano = anomocytic, ani = anisocytic, para = paracytic, dia = diacytic

Taxa		Type				E	Dimension		F	Index	Rim width	Ap. area
		ano	ani	dia	para		width (µm)	length (µm)	(mm^{-2})		(µµ)	($µm_{.}$)
Markhamia obtussiflora	Ab	+	–	–	–	A	15.0(16.0)17.0	16.0(17.9)18.6	31	35.6	3.87	51.10
Markhamia lutea	Ab	+	–	–	–	A	10.6(11.6)12.3	12.4(13.4)14.5	28	26.1	4.01	24.71
Markhamia tomentosa	Ab	+	–	+	–	A	12.4(13.5)14.5	18.3(20.6)21.8	24	26.9	6.65	57.26
Tabebuia palluda	Ab	+	–	+	–	C	8.9(9.9)10.3	9.3(10.3)11.9	15	16.3	4.50	16.22
Tecomaria capensis	Ab	+	–	–	–	C	10.6(11.3)12.8	14.7(15.8)16.8	18	25.00	3.49	36.94
Newbouldia leavis	Ab	+	–	–	–	C	8.9(9.9)10.0	12.9(13.2)14.3	14	22.9	2.76	25.85
Jacaranda mimosifolia	Ab	+	–	–	–	B	4.3(5.9)6.7	7.2(8.8)9.3	50	41.7	2.08	11.29
Stereospermum kunthianum	Ab	–	–	–	+	C	8.1(9.1)10.9	10.9(11.2)12.3	51	40.5	5.57	18.41
Stereospermum acuminatissimum	Ab	+	–	–	–	B	9.2(10.4)11.2	12.1(13.3)14.4	60	43.32	3.99	23.31
Kigelia africana	Ab	–	–	+	–	C	7.9(8.9)9.3	11.7(12.2)13.4	27	36	4.11	20.66
Parmentiera cerufera	Ab	+	–	–	–	C	13.9(14.4)15.4	15.7(16.8)17.3	20	27.43	2.50	42.52
Parmentieae venusta	Ab	+	–	–	+	A	11.3(12.3)13.2	22.3(23.3)24.7	9	7.5	3.12	56.33
Haplophragma adenophylla	Ab	–	+	–	–	A	11.1(12.8)13.9	15.3(16.4)17.4	47	41.2	4.37	37.93
Rhodocolea racemosa	Ab	–	+	–	–	B	10.2(11.2)12.4	20.2(22.2)24.5	14	21.3	4.01	45.56
Crescentia cujete	Ab	+	–	–	+	B	10.5(11.3)12.4	15.4(16.3)17.3	10	16.7	3.95	7.89
Spathodea campanulata	Ab	+	+	–	–	B	5.3(6.7)7.4	8.3(9.1)10.1	35	40.3	2.54	10.63

Stomatal frequency (i.e. number of stomata per ×40 field). Varied from 9 in *P. venusta* to 60 in *Stereospermum acuminatissimum*.

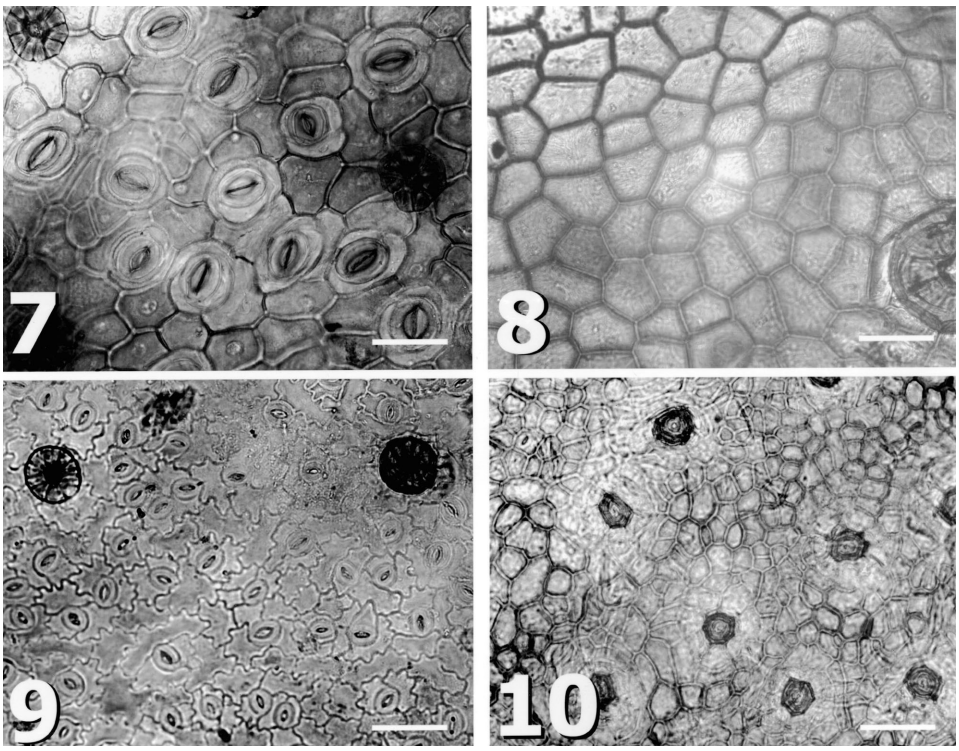
Stomatal index (i.e. percent of number of stomata over number of stomata and number of cell per H.P. field). The lowest stomatal index was recorded in *P. venusta* (7.5) and highest in *Stereospermum acuminatissimum* (43.3).



Figs 1–6. General characteristics of epidermal cells. 1–2 = *Parmentiera venusta*: 1 = Abaxial, 2 = Adaxial; 3–4 = *Haplophragma adenophylla*: 3 = Abaxial, 4 = Adaxial; 5–6 = *Parmentiere cerufera*: Adaxial. All scale bars = 50 μm

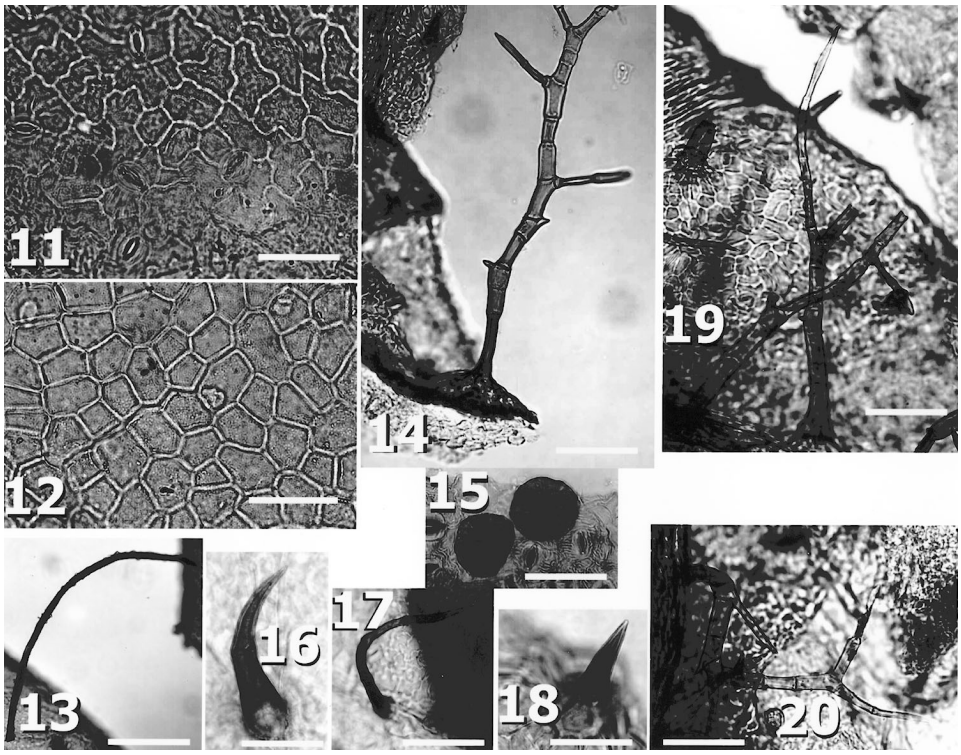
Venation (Table 1, Figs 21–26): pinnate, eucamptodromous or brochidodromous. Primary vein (midrib) of thick in size, straight, unbranched. Secondary veins diverging acute, moderate, divergence angle (45° to 65°) nearly uniform; thick; curved uniformly, unbranched loops joining super adjacent secondaries at acute angle, enclosed by weak tertiary arches. Tertiaries are current, concave or convex, more or less at right angles or oblique to the primary vein, arranged alternate and opposite in equal proportions. Quarternary veins are more pronounced on the abaxial than the adaxial surface. Veinlets are absent in *M. obtussiflora*, *M. tomentosa, J. mimosifolia*, absent or simple in *Tabebuia palluda*, *Stereospermum acuminatissimum* and *P. venusta*. In the others they are complex. Areolations are well developed and orientated, quadrangular or pentagonal and large in size.

Trichomes (Figs 4–5, 13–20, 30, 32, 37, 41, 45, 47, 49, 51, 55, 57, 60–67): simple and glandular trichomes are present and abundant to common in frequency in all species. In *Tabebuia palluda*, *M. obtussiflora* (Fig. 68) and *Spathodea campanulata*, scars of trichomes were observed. Four types of simple trichome



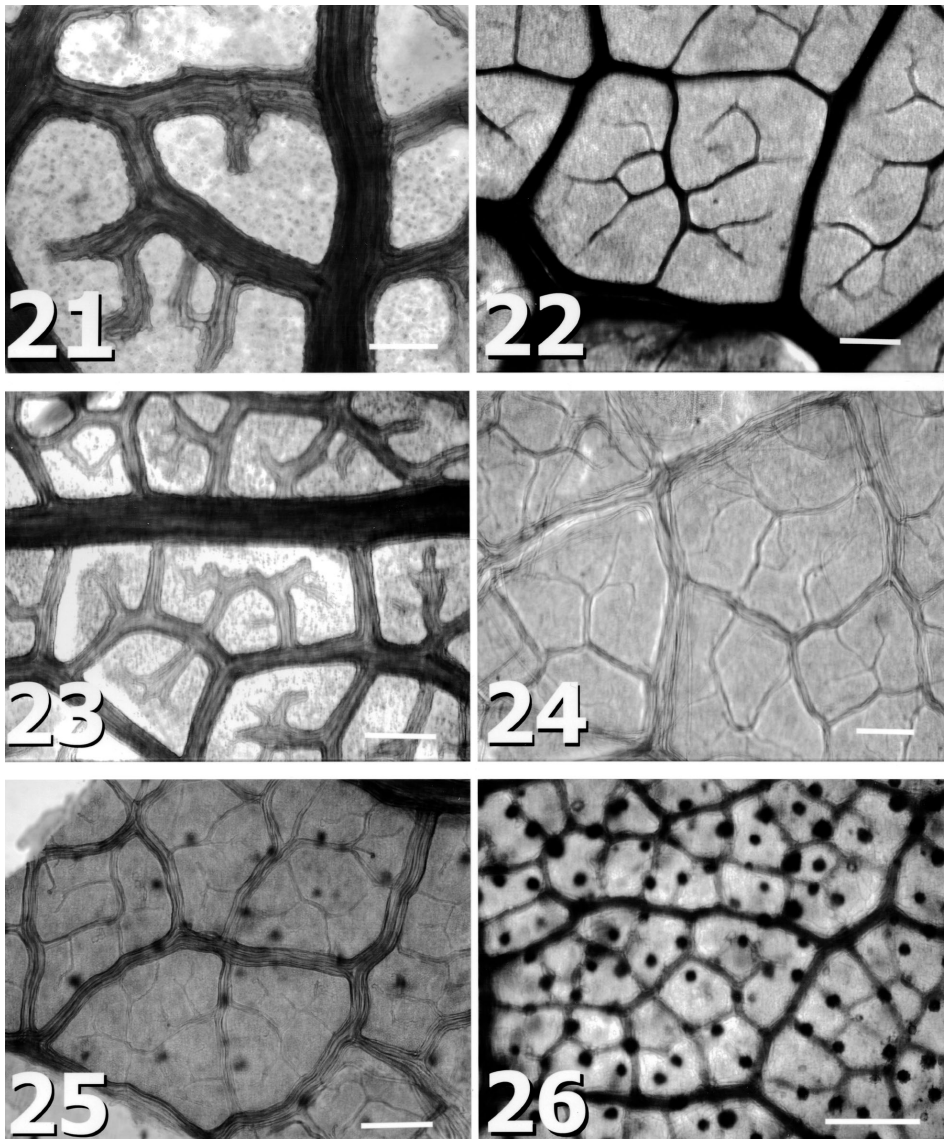
Figs 7–10. General characteristics of epidermal cells. 7–8 = *Rhodocolia racemosa*: 7 = Abaxial, 8 = Adaxial; 9–10 = *Newbouldia leavis*: 9 = Adaxial, 10 = Adaxial. All scale bar = 50 μm

were observed, large and small acicular (Figs 4, 16, 18, 32, 62, 65); subulate (Figs 5, 30, 60); filiform (Figs 13, 17, 34, 53, 57, 61, 63); which appressed to the surface and antrorse; fasciculate (Figs 55, 64). Multicellular trichomes with a cluster of 2–10 unicellular rays in a single set and more or less erect were observed in *H. adenophylla* but absent in other species. Simple and complex dendric are present (Figs 14, 19–20). Simple dendric type has raised basal cell (Fig. 14), while the complex dendristic type has basal cell on the same level with the surrounding cells (Figs 19–20). The dendric type is abundant on veins of *Tecomaria capensis* and *Tabebuia palluda*. The other types are commonly distributed on the veins and areolea of other species. In *H. adenophylla*, fasciculate trichomes are present (Figs 55, 57). The ornamentation of the hair is clearly seen with SEM (Figs 30, 32, 55, 60–65).



Figs 11–20. General characteristics of epidermal cells. 11–12 = *Cresentia cujete*: 11 = Abaxial, 12 = Adaxial. Scale bars = 50 µm. 13–20 = Trichome types: 13 and 17 = Filiform type, 13 = *Spathodea campanulata*, 17 = *Newbouldia leavis*, 14, 19 and 20 = Dendric type, 14 = *Tecomaria capensis*, 19–20 = *Tabebuia palluda*, 16 and 18 = *Kigelia africana*, acicular type, 15 = *Newbouldia leavis* peltate glands. Scale bars = 15 µm

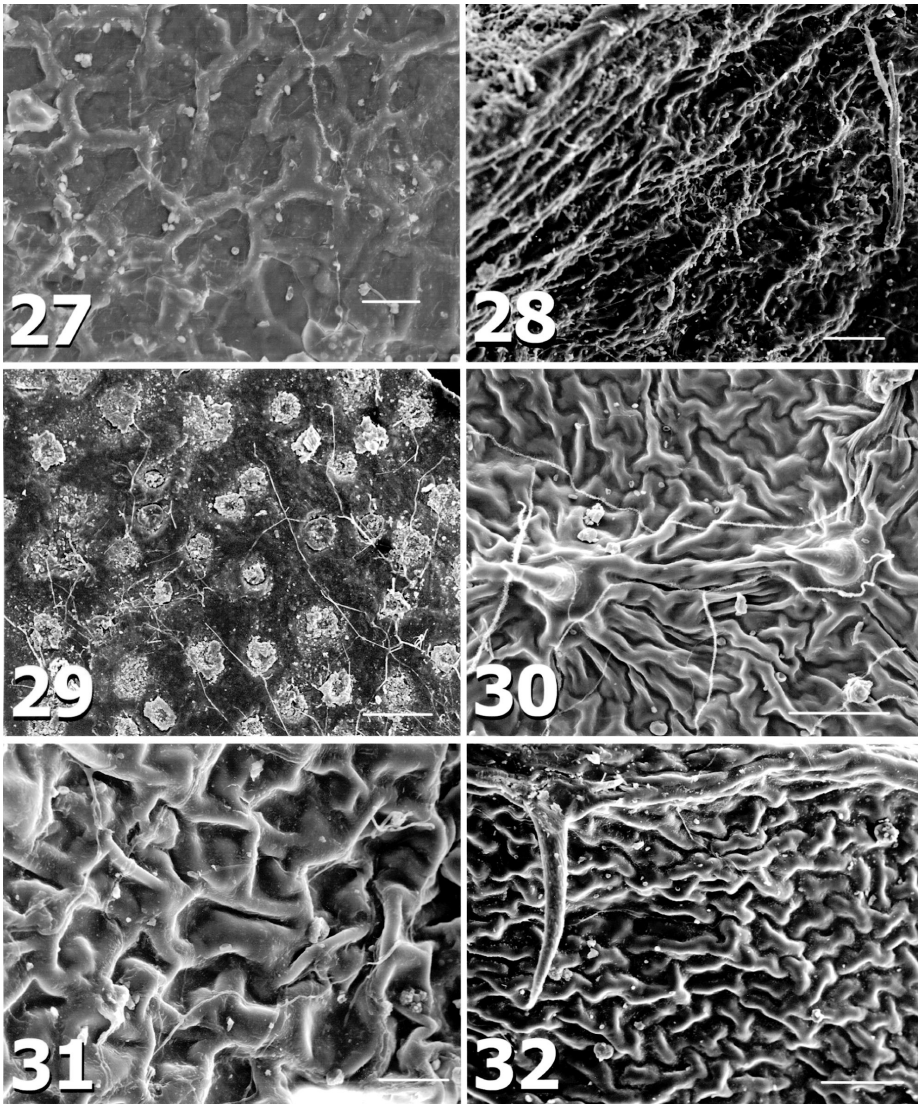
Glandular trichomes are present in the form of peltate scales (Figs 41, 45, 47, 49, 51, 66–67) or capitate glands. Peltate scales are common in different frequencies in all the species, but capitate glands are present only in *N. leavis*, *J. mimosifolia*, *K. africana*, *Spathodea campanulata* and *Tabebuia palluda*.



Figs 21–26. Venation pattern. 21 = *Kigelia africana*, 22 = *Newbouldia leavis*, 23 = *Haplophragma adenophylla*, 24 = *Rhodocolea racemosa*, 25 = *Markhamia lutea*, 26 = *Tabebuia palluda*. All scale bars = 20 μm

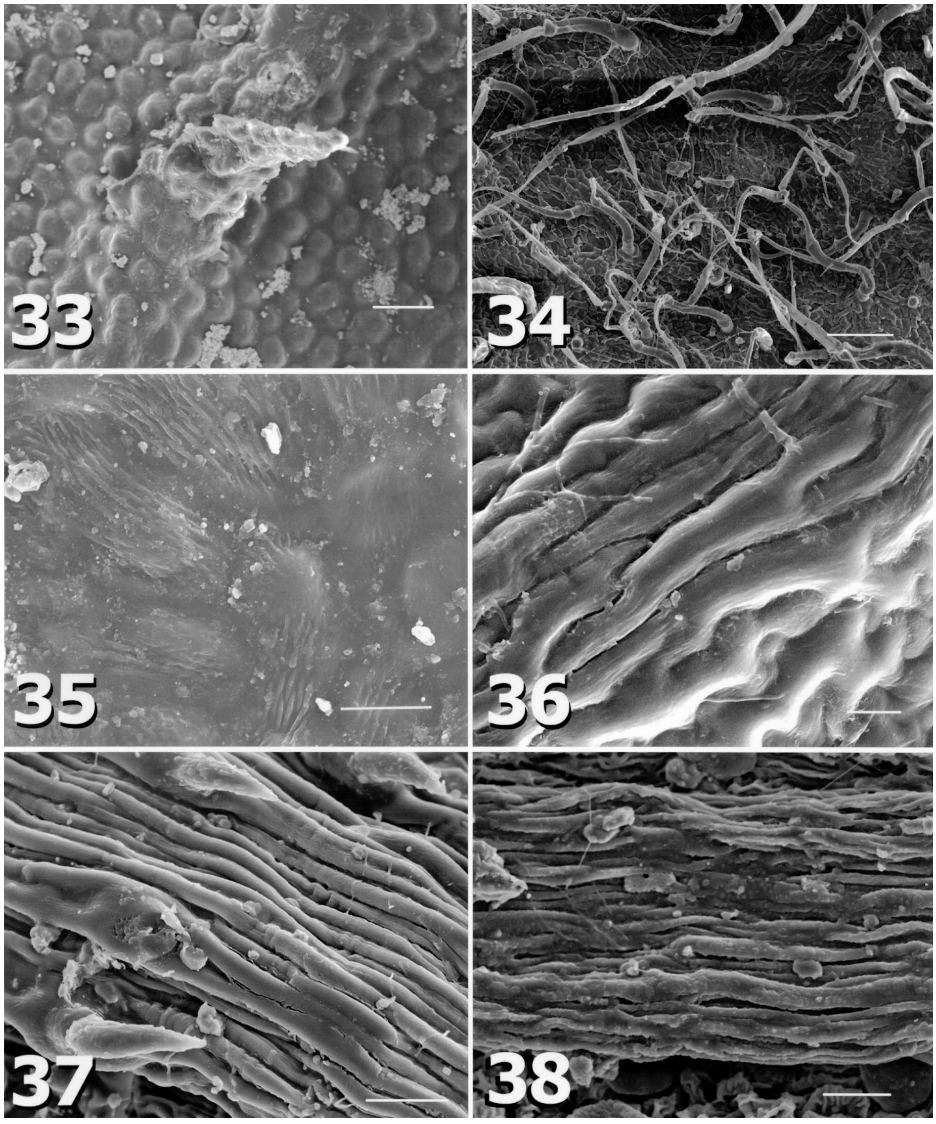
T. S. Lamina

Mesophyll: dorsiventral in most species but isobilateral in *M. lutea*, *N. leavis*, *H. adenophylla* and *K. africana*. **Cuticle**: not very thick in most species, but



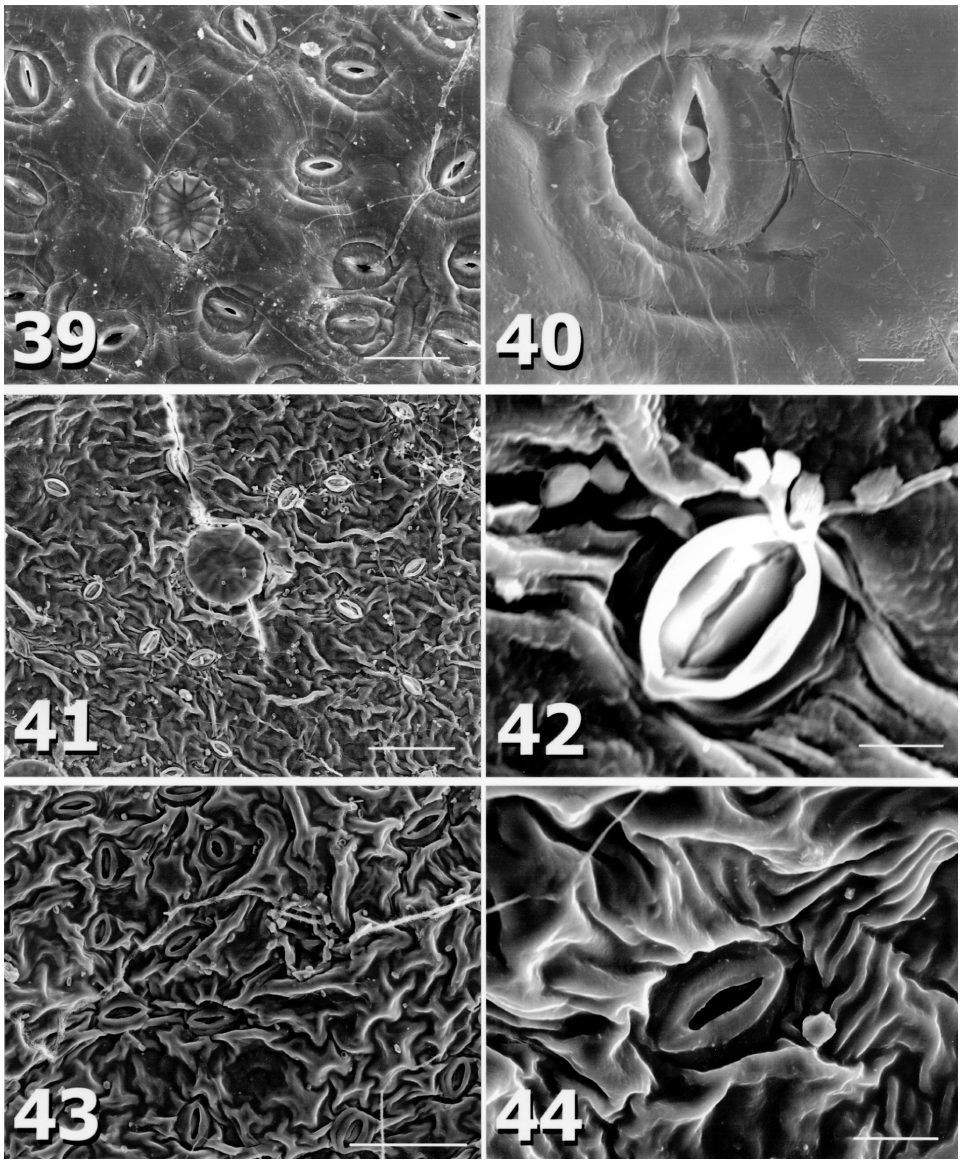
Figs 27–32. Adaxial epidermal surfaces. 27 = *Crescentia cujete*, scale bar = 20 μm, 28 = *Markhamia lutea*, scale bar = 50 μm, 29 = *Tabebuia palluda*, scale bar = 100 μm, 30 = *Tecomaria capensis*, scale bar = 50 μm, 31 = *Jacaranda mimosiflora*, scale bar = 20 μm, 32 = *Parmentiera cerufera*, scale bar = 50 μm

thicker on the adaxial than the abaxial surface. **Epidermal cells**: usually large and thick-walled on abaxial surface. Anticlinal cells are straight, arcuate. Outer periclinal wall cellulose and usually thicker than other walls. **Hypo-**



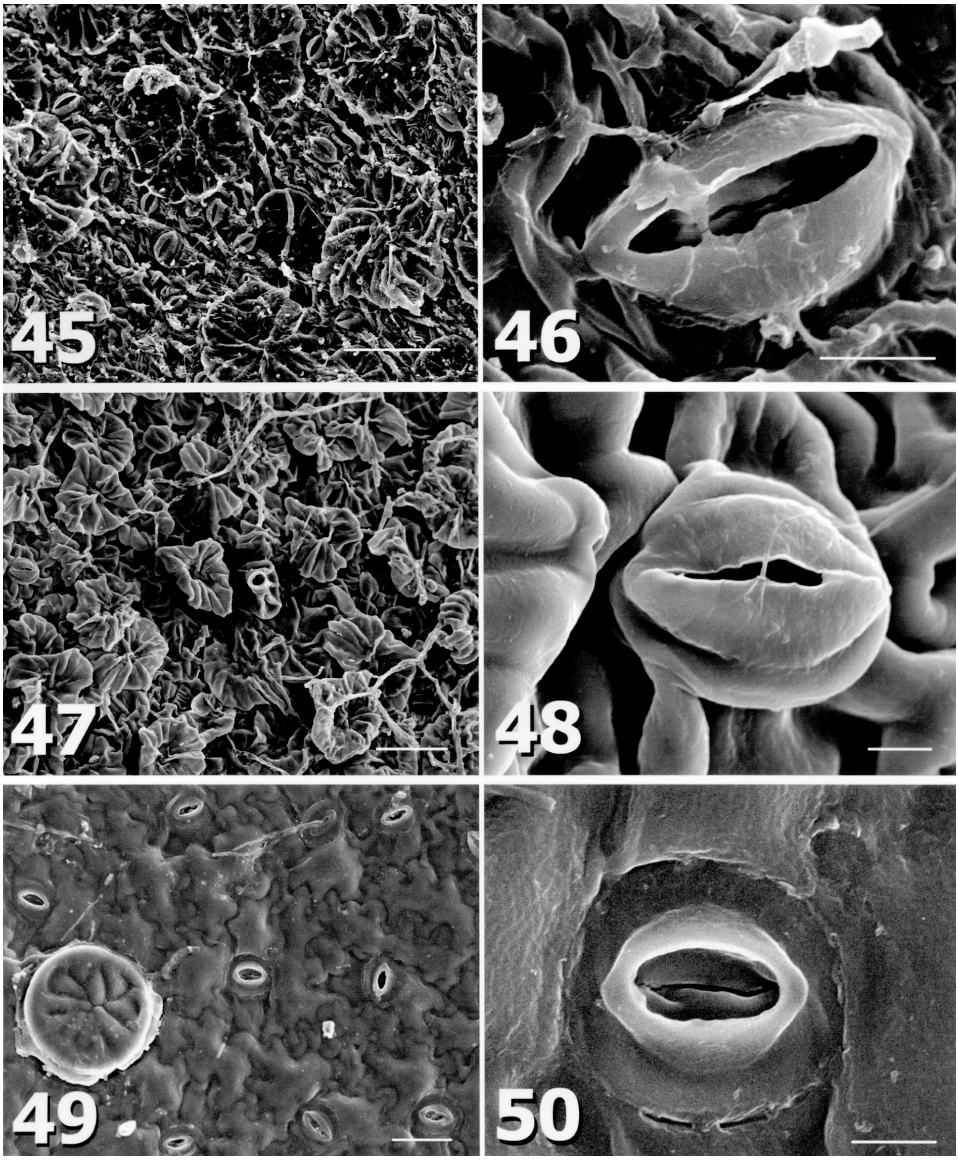
Figs 33–38. Adaxial epidermal surfaces. 33 = *Haplophragma adenophylla*, scale bar – 20 µm, 34 = *Markhamia obtussiflora*, scale bar – 100 µm, 35 = *Parmentiera venusta*, scale bar – 20 µm. 36–38 = Costal zone: 36 = *Newbouldia leavis*, scale bar – 10 µm, 37 = *Tecomaria capensis*, scale bar – 20 µm, 38 = *Parmentiera venusta*, scale bar – 50 µm

dermis: thick-walled, 1–5 layers in *Stereospermum acuminatissimum*, *S. kunthianum*, and *R. racemosa*, but not seen in other species. Palisade one layered in all species. A transition layer occurs between the palisade and the spongy meso-



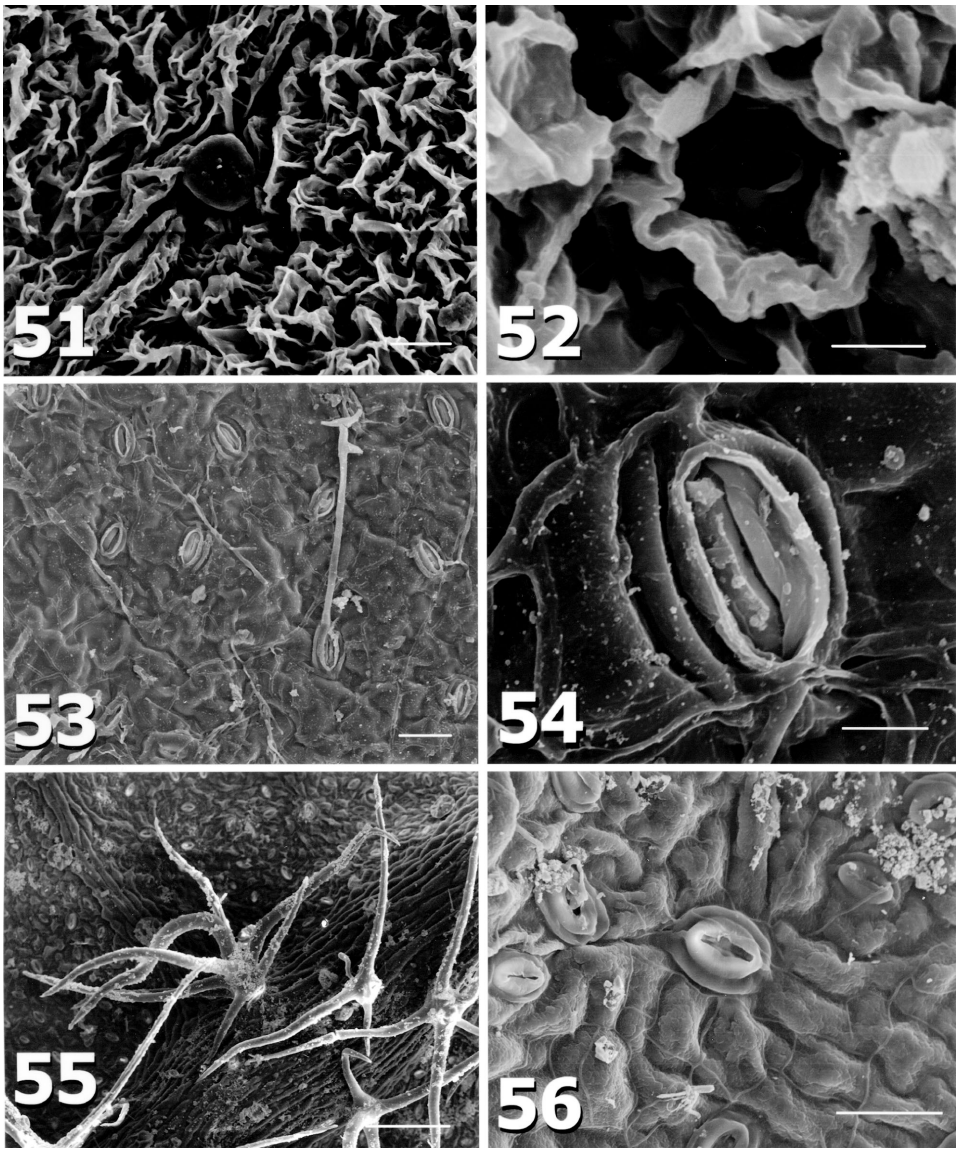
Figs 39–44. Abaxial epidermal surfaces. 39–40 = *Rhodocolea racemosa*: 39: scale bar – 50 µm, 40: scale bar – 10 µm; 41–42 = *Crescentia cujete*: 41: scale bar – 50 µm, 42: scale bar – 5 µm; 43–44 = *Tecomaria capensis*: 43: scale bar – 50 µm, 44: scale bar – 10 µm

phyll in *Tecomaria capensis*, *M. obtussiflora*, *M. tomentosa*, *N. leavis* and *H. adenophylla*. Spongy mesophyll is composed of thick-walled sclerenchymatous idioblasts on *K. africana*, *N. leavis*, *M. lutea* and *H. adenophylla*.



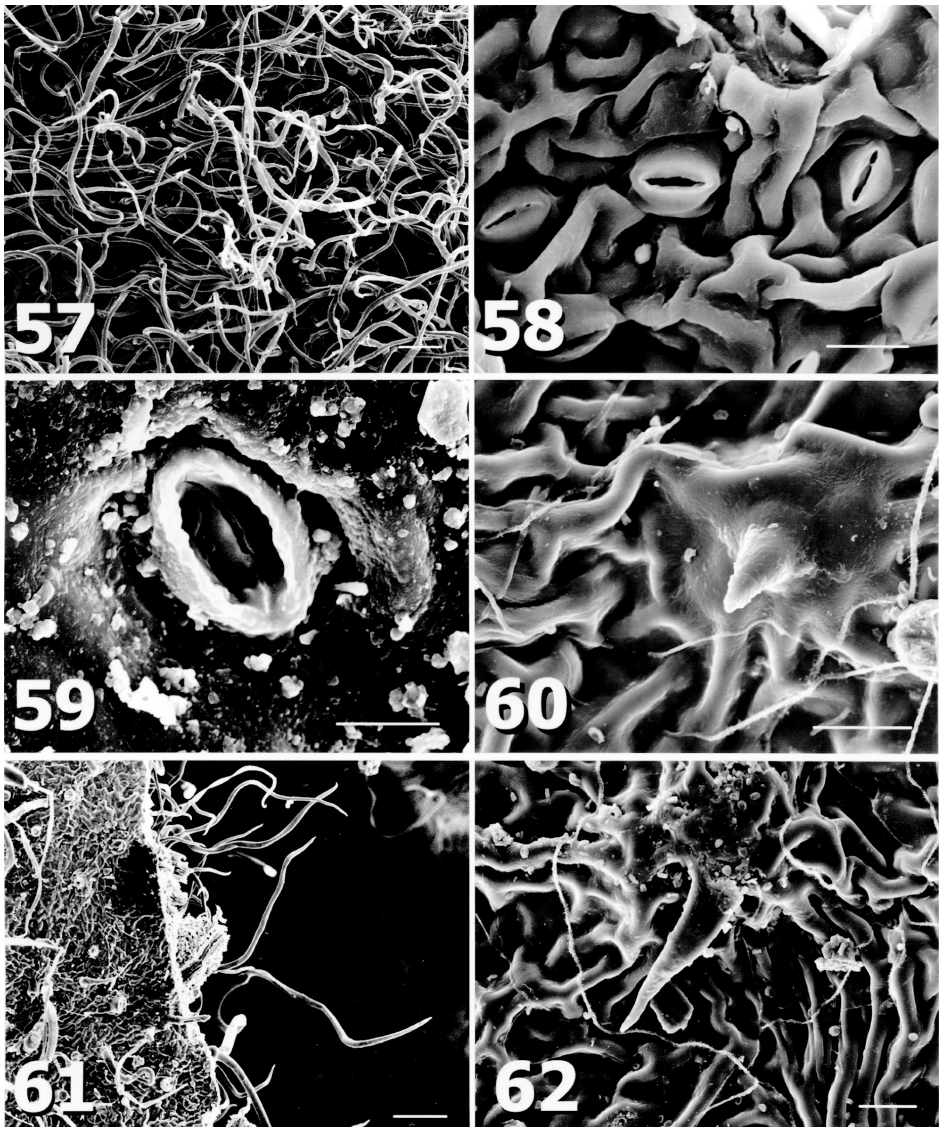
Figs 45–50. Abaxial epidermal surfaces. 45–46 = *Markhamia lutea*: 45, scale bar = 50 µm, 46, scale bar = 5 µm; 47–48 = *Markhamia tomentosa*. 47, scale bar = 50 µm, 48, scale bar = 5 µm; 49–50 = *Newbouldia leavis*. 49, scale bar = 20 µm, 50, scale bar = 5 µm

Midrib (Fig. 69): Usually flat or slightly groove on the adaxial surface and prominent abaxial ridge. Midrib mainly supported by collenchyma. The ground parenchyma contains sclerenchymatous fibres in *C. cujete*, *R. racemosa*,



Figs 51–56. Adaxial epidermal surfaces. 51–52 = *Jacaranda mimosifolia*: 51, scale bar = 20 µm, 52, scale bar = 5 µm; 53–54 = *Stereospermum kunthianum:* 53, scale bar = 20 µm, 54, scale bar = 5 µm; 55–56 = *Haplophragma adenophylla*: 55, scale bar = 100 µm, 56, scale bar = 50 µm

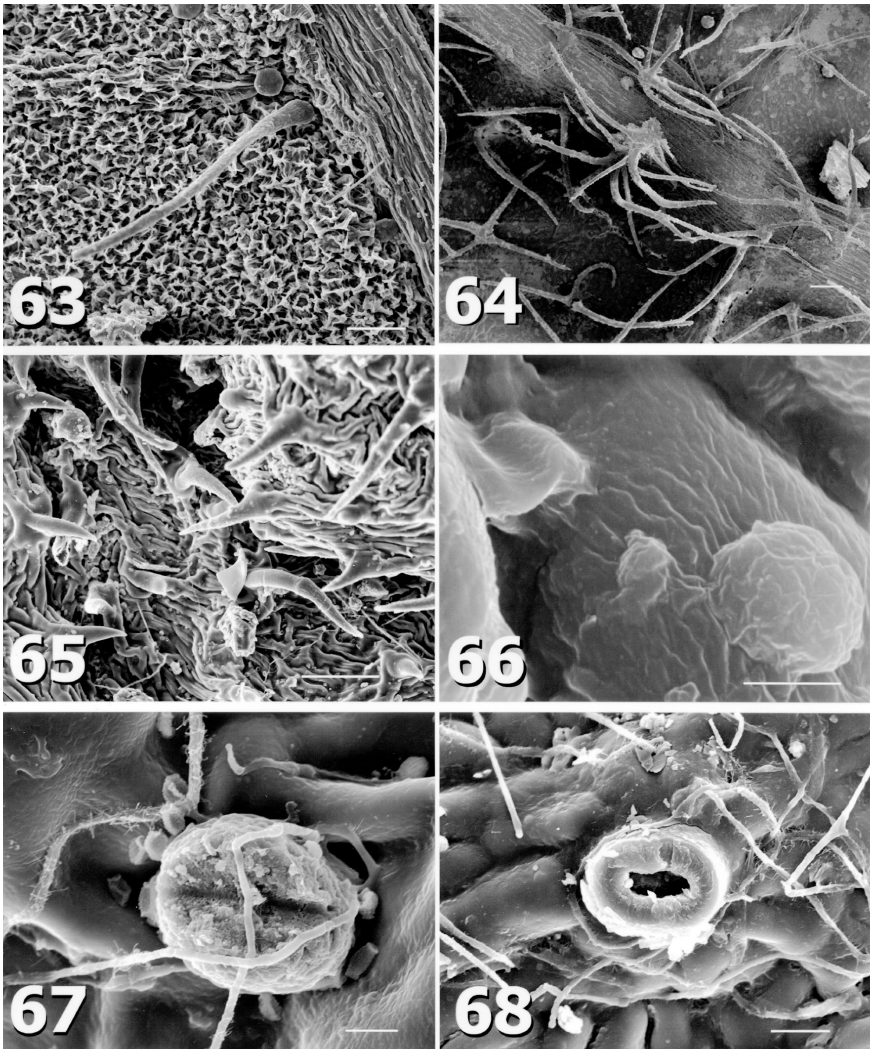
Stereospermum acuminatissimum and *K. africana*. **Vascular bundle**: the midrib contains an interrupted ring of collateral bundles. **Crystals**: present in the form of crystal sands, starch grains, prisms and octahedra.



Figs 57–59. Abaxial epidermal surfaces. 57–58 = *Markhamia obtussifolia*: 57, scale bar – 100 µm, 58, scale bar – 10 µm, 59 = *Tabebuia palluda:* scale bar – 10 µm. *Figs 60–62.* Trichome type. 60 = *Tecomaria palluda*, subulate trichome, scale bar – 20 µm, 61 = *Tabebuia palluda*: filiform trichome, scale bar – 100 µm, 62 = *Tecomaria palluda*: acicular trichome, scale bar – 20 µm

T. S. Petiole (Fig. 70)

Circular to oval in outline. Epidermal cells 2–3 times higher than wide. **Outer tissues**: collenchyma absent in all the species except in *R. racemosa* and *H. adenophylla* where it is sparsely distributed between epidermis and first



Figs 63–68. Trichome type. 63 = *Jacaranda mimosiflora*: filiform, scale bar – 50 µm. 64 = *Haplophragma adenophylla*: fasciculate, scale bar – 100 µm, 65 = *Tecomaria palluda*: acicular and filiform trichomes, scale bar – 50 µm. 66–67 = *Stereospermum acuminatissimum*: peltate glands. 66, scale bar – 25 µm, 67 = scale bar – 5 µm, 68 = *Markhamia obtussiflora*: trichome scar, scale bar – 5 µm

layer of cortical cells. **Vascular system**: closed ring, which is sometimes dissected into separate bundles. **Bundle sheath**: sclerenchymatous, strands of fibres usually completely or incompletely encircling main vascular system. **Central tissues**: parenchymatous. **Crystal**: prismatic in phloem and parenchyma.

DISCUSSION

Significant anatomical features

Carlquist (1961) has stated that the leaf is "perhaps anatomically the most varied organs of angiosperm…". The importance of micro-morphology and

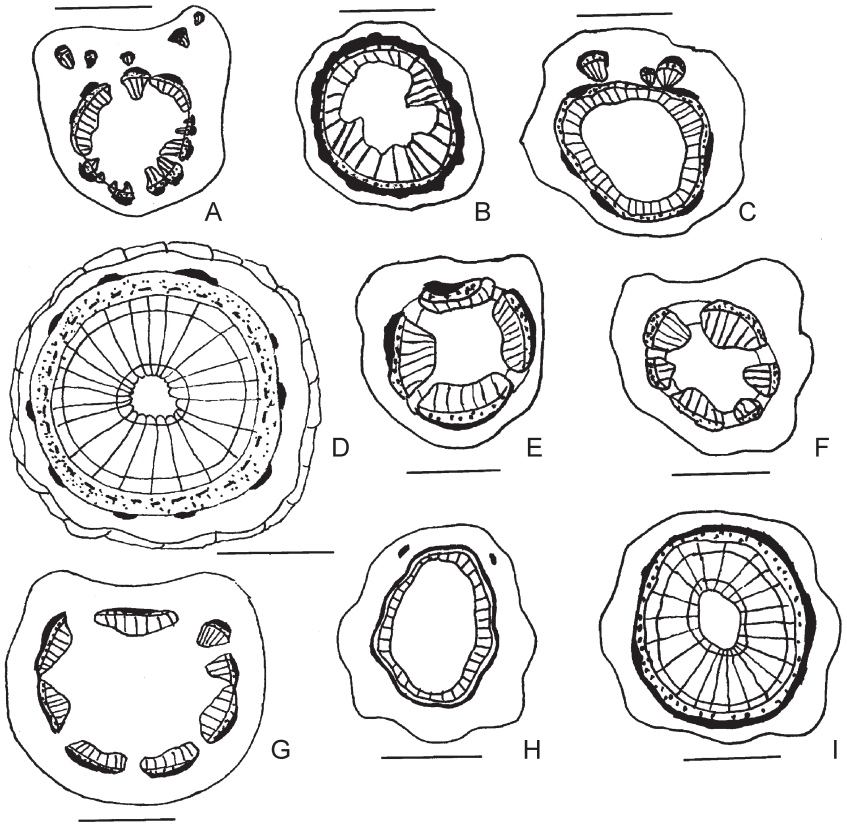


Fig. 69. Transverse sections of petiole. (A = *Kigelia africana*, B = *Spathodea campanulata*, C = *Newbouldia leavis*, D = *Tecomaria capensis*, E = *Parmentiera venusta*, F = *Rhodocolea racemosa*, G = *Stereospermum acuminatissimum*, H = *Tabebuia palluda*, I = *Jacaranda mimosiflora*. All scale bars = 500 μm)

anatomy of the leaf was recognised by other workers such as Tomblinson (1959), Davis and Heywood (1973), Wilkinson (1982), Cutler (1984), Barthlott (1990), Hardin (1992) and Dickie and Gasson (1999), among others.

The primary object of this study was to provide a full description of the leaf anatomy of 12 genera of the family Bignoniaceae and to establish an up-to-date identification for the taxa in this family.

The study confirms the taxonomic usefulness of leaf anatomical features in showing affinities between species and defines the position of a given species. The preceding observations and summaries in Tables 1 and 2 indicate that the species could be divided into groups based on the leaf anatomical characters. However, some characters are diagnostic features for all genera in the family, such as presence of peltate glandular trichomes. Leaves are dorsiventral in all except *M. lutea*, *N. leavis*, *H. adenophylla* and *K. africana* where they were isobilateral. They have a single layer of palisade with variable height (Metcalfe and Chalk 1979). The presence of one or more layers of hypodermis

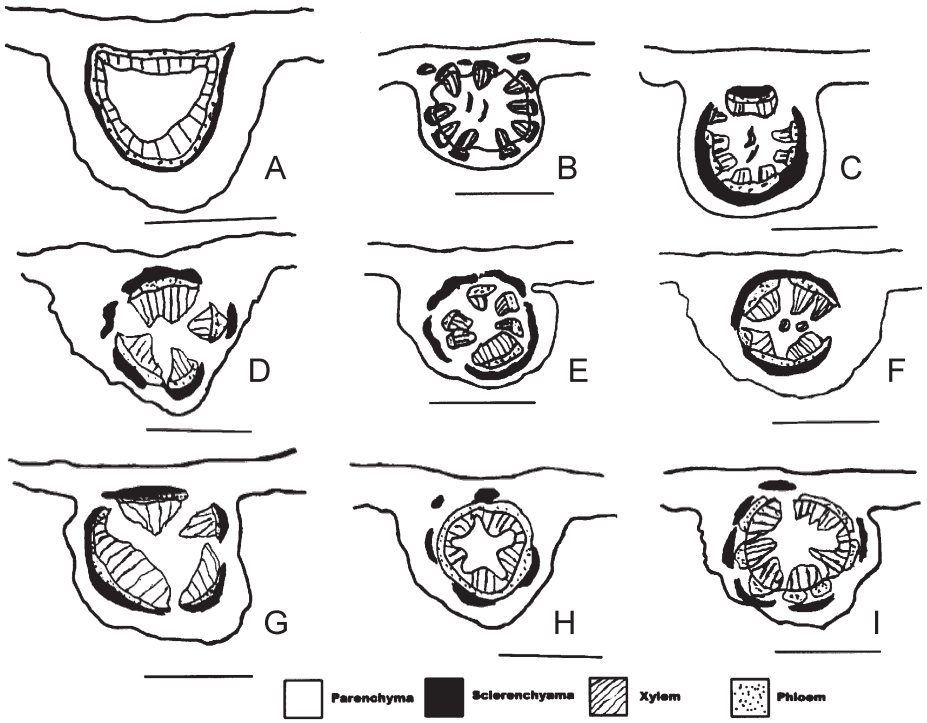


Fig. 70. Transverse sections of midrib. (A = *Spathodea campanulata*, B = *Kigelia africana*, C = *Tabebuia palluda*, D = *Newbouldia laevis*, E = *Stereospermum acuminatissimum*, F = *Tecomaria capensis*, G = *Jacaranda mimosiflora*, H = *Parmentiera venusta*, I = *Rhodocolea racemosa*. All scale bars are 500 μm)

as characterised by Metcalfe and Chalk (1979) was recorded in *Stereospermum acuminatissimum*, *S. kunthianum*, and *R. racemosa w*hile hypodermis is absent in all others. In the mesophyll sclerenchymatous idioblasts were recorded in *K. africana*, *N. leavis*, *M. lutea* and *H. adenophylla*.

The importance of trichomes in the identification and classification of species is supported by Carlquist (1961), Rao (1991) and Hardin (1992). In this study, four types of trichomes were recorded; acicular, which may be long or short were present in all except *M. lutea*, *M. tomentosa*, *Stereospermum kunthianum*, *P. cerufera*, *H. adenophylla* and *R. racemosa*. Filiform trichomes, which are curled or wavy, were recorded in *M. lutea*, *M. tomentosa*, *Tabebuia palluda*, *Stereospermum kunthianum*, *S. acuminatissimum*, *K. africana*, *P. cerufera* and *Spathodea campanulata*. In *M. obtussiflora*, *N. leavis* and *Tabebuia palluda* filiform trichomes are appressed to the surface and are antrorse. Subulate, which is awl-shaped and stiff, are present in *Tabebuia palluda* and *Tecomaria capensis* only. Fasciculate, multicellular trichomes clusters of 2–10 unicellular rays in a single set and more or less erect were observed in *H. adenophylla* but absent in other species. Dendric trichomes, which may be simple or complex, were recorded in *Tabebuia palluda* and *Tecomaria capensis*. Simple dendric trichomes with raised basal cells were present only in *Tecomaria capensis,* while in *Tabebuia palluda*, both simple and complex types of dendric trichomes were observed.

Glandular trichomes were of two types. Peltate scales were found in all the taxa and capitate glands were present in only *Tabebuia palluda*, *N. leavis*, *J. mimosifolia* and *K. africana*.

Metcalfe and Chalk (1979) reported paracytic and diacytic types of stomata with variable number of ordinary epidermal cells. In this study anomocytic, anisocytic, diacytic and paracytic stomata type or in varying combinations are

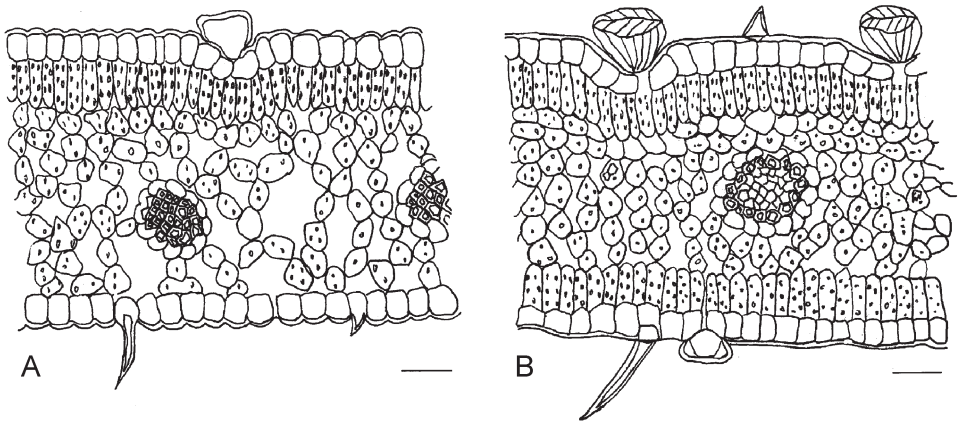


Fig. 71. Transverse sections of mesophyll. (A = *Kigelia africana*, B = *Markhamia lutea*. All scale bars are 200 μm)

reported (Table 1). Anomocytic only with 4–6 ordinary epidermal cells were present in all species except in *K. africana*, which possessed the diacytic type, *Stereospermum kunthianum* paracytic, *R. racemosa* anisocytic type, *M. tomentosa*, *Tabebuia palluda* anomocytic and diacytic, *Spathodea campanulata* and *N. leavis* with anomocytic and anomocytic types of stomata. Stomata are confined to the lower epidermis (hypostomatic) in all species. Peristomatic ridges were present in *J. mimosifolia*, *Tabebuia palluda* and *C. cujete*.

Wilkinson (1979), Stace (1965), Barthlott (1990), Hardin (1988, 1992) among others have drawn attention to the taxonomic importance of cuticular ornamentation. In this study, cuticular patterns were smooth, striated or ridged. The adaxial and abaxial epidermises were striated in *Stereospermum acuminatissimum* and *P. venusta*, but on the abaxial surface in *M. lutea*, *M. tomentosa*, *K. africana* and *H. adenophylla*. They are ridged on the adaxial surface of *J. mimosifolia*, and the adaxial surface of *C. cujete*, while smooth in all others.

Wilkinson (1979) stated that wax morphology is particularly useful as an additional diagnostic character (Barthlott and Wollenweber 1981). Its importance in species identification and classification varies from species to species. Hallam and Juniper (1971) and Barthlott (1981) have suggested an anti-contamination effect, as probably the most important aspect of the widespread of epicuticular wax crystalloid found in plants. Fourteen taxa of Bignoniaceae studied have granular epicuticular wax, but in *J. mimosifolia* and *P. venusta* wax occurs as flakes.

The appearance of anticlinal walls at the surface is another important feature in the taxa of Bignoniaceae. They are generally straight to arcuate on the abaxial surface of *M. obtussiflora*, *M. lutea*, *M. tomentosa*, *Tabebuia palluda*, *Tecomaria capensis*, *R. racemosa*, *C. cujete* and *Spathodea campanulata*, but arcuate to sinuous or sinuous in all others. On the adaxial surface the anticlinal walls were generally straight except in *H. adenophylla* and *P. cerufera* where they were straight to arcuate. Workers such as Stace (1965) and Barthlott (1981) have stated the importance of anticlinal walls pattern.

TAXONOMIC IMPLICATIONS OF CHARACTERS

The data show combinations of leaf anatomical characters that are useful in the identification of the twelve genera of Bignoniaceae studied. At the same time the leaves of all the species have some anatomical features in common. This study suggests that the diverse anatomical characters that can be of diagnostic importance include = sclerenchymatous idioblasts in the mesophyll; hypodermis and schlerenchymatous fibres in the ground tissue; collenchyma in the outer tissue of the petiole; peristomatic ridges, which put the taxa into

two groups; cuticular patterns which can be used to group the taxa in three groups; two major types of trichomes, four sub-types of non-glandular and two subtypes of glandular; stomata which are paracytic, diacytic, anomocytic, anisocytic, diacytic and anomocytic, paracytic and anomocytic, and anisocytic and anomocytic; the type of sinuous epidermal anticlinal cells, especially on the abaxial surface which can be straight/arcuate to arcuate/sinuous or sinuous; veinlets termination number and palisade ratio.

KEY TO THE SPECIES OF WEST AFRICAN BIGNONIACEAE BASED ON FOLIAR ANATOMY

1	Glandular trichomes; capitate glands	2
1	Glandular trichomes; capitate glands absent	6
2	Abaxial epidermis ridged	*Jacaranda mimosifolia*
2	Abaxial epidermis smooth	3
3	Dendric trichomes present	*Tabebuia palluda*
3	Dendric trichomes absent	4
4	Adaxial epidermis striated	*Kigelia africana*
4	Adaxial epidermis smooth	5
5	Scar of trichomes present	*Spathodea campanulata*
5	Scar of trichomes absent	*Newbouldia leavis*
6	Adaxial epidermis striated	7
6	Adaxial epidermis not striated	8
7	Filiform trichomes present	*Stereospermum acuminatissimum*
	Filiform trichomes absent	*Parmentiera venusta*
8	Adaxial epidermis ridged	*Crescentia cujete*
8	Adaxial epidermis not ridged	9
9	Dendric trichomes present	*Tecomaria capensis*
9	Dendric trichomes absent	10
10	Fasciculate trichomes present	*Haplophragma adenophylla*
10	Fasciculate trichomes absent	11

11	Scars of trichomes present	*Markhamia obtussiflora*
11	Scar of trichomes absent	12
12	Veinlets absent	*Markhamia tomentosa*
12	Veinlet simple or complex	13
13	Abaxial cells polygonal and anticlinal walls straight or straight to arcuate	14
13	Abaxial cells polygonal and anticlinal walls straight or straight to arcuate	15
14	Filiform trichomes present	*Markhamia lutea*
14	Filiform trichomes absent	*Rhodocolea racemosa*
15	Stomata type = paracytic	*Stereospermum kunthianum*
15	Stomata type = anomocytic	*Parmentiera cerufera*

*

Acknowledgements – We thank G. Williams who gave technical advice on preparation and observation of material. O. T. Ogundipe's visit to the U.S.A. was supported by funding through University of Lagos, CMU's Office of International Education, Dean of the College of Science and Technology, and the Department of Biology.

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APPENDIX
Source of material examined

Markhamia obtussiflora Seem. ex Baillon	Olatunji 5912 (IFE); Ogundipe 433 (LUH)
Markhamia lutea (Benth) K. Schum.	FHI 40321; Ogundipe 512 (LUH); Olatunji 5203 (IFE)
Markhamia tomentosa (Benth) K. Schum.	Elliott 89; FHI 16597; Ogundipe 1012 (LUH)
Tabebuia palluda Gomes ex DC.	Ogundipe 910 (LUH); 850; Olatunji 5334 (IFE)
Tecomaria capensis (Spach) Thunberg	Ogundipe 610 (LUH); 656 (LUH)
Newbouldia leavis (P. Beauv.) Seem. ex Bureau	Olatunji 918 (LUH); Ogundipe 512 (LUH); 491 (LUH)
Jacaranda mimosifolia Juss.	Olatunji 6875 (IFE); Ogundipe 893 (LUH), 897 (LUH), 975 (LUH)
Stereospermum kunthianum Cham.	Ajala 25 (IFE); FHI 288324; Ogundipe 666 (LUH)
Stereospermum acuminatissimum K. Schum.	FHI 38275; Ogundipe 743 (LUH)
Kigelia africana (Lam.) Benth.	FHI 28952; Ogundipe 474 (LUH); 524 (LUH)
Parmentiera cerufera DC.	Ogundipe 612 (LUH); 783 (LUH)
Parmentiera venusta DC.	Ogundipe 1265 (LUH); 1376 (LUH)
Haplophragma adenophylla (Wall. ex G.) Dop.	Ogundipe 1128 (LUH); 1243 (LUH)
Rhodocolea racemosa Baill.	Ogundipe 1058 (LUH); 920 (LUH)
Crescentia cujete Linn.	Ogundipe 848 (LUH); Olatunji 6738 (IFE)
Spathodea campanulata P. Beauv.	Ogundipe 223 (LUH); Olatunji 7321 (IFE); FHI 28741